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B.Sc(PS)Computer Science VI Sem
Dielectrics

DIELECTRICS.

→ Dielectrics are non-conductors of electricity (electrical insulators) because they do not possess free charges.
→ In such substances e^- are very tightly bound to the atoms & electrical conductivity is very small or zero.
→ E.g are asbestos, ~~ceramics~~ ceramics, ~~resins~~ resins, mica, wood, glass etc → solids.
Pure water, methyl chloride, H_2, N_2, Ammonia etc. are e.g of liquids & gases. Energy gap ~ 3eV.

→ As e^- are tightly bound to the atoms, they do not conduct any current, and at ordinary temp. They cannot be dislodged either by thermal vibrations or with ordinary fields.
→ The negative and positive charges in each atom of the crystal can be considered to be centered at the same point and so no conductivity is possible, the localized charges remain practically undisturbed. When an electric field of sufficient magnitude is applied to the crystal, the centres of positive charges are displaced slightly in one direction i.e the direction of field and that of the negative charges in the opposite direction. This produces local electric dipole throughout the crystal. A dielectric is called homogenous and isotropic if all its properties are same at any point and in all directions inside it.

P.T.O

Dielectric Parameters:-

Dielectric Parameters are:-

(i) Dielectric constant (ϵ_r):- It is defined as the ratio of permittivity of medium (ϵ) to the permittivity of free space (ϵ_0).

$$\epsilon_r = \epsilon / \epsilon_0$$ dimension less quantity

measure of dielectric constant or relative permittivity gives the properties of the dielectric material.

(ii) Electric dipole moment:- An electric dipole is made up of two equal positive and negative charges, separated by a small distance.

$$\vec{p} = q\,d\vec{l}$$ where $q \rightarrow$ mag. of charge, $dl \rightarrow$ sepration.

p is a vector quantity (Cm) p - dipole moment

Total dipole moment of the solid will be

$$\vec{P}_{total} = \sum_{i=1}^{n} q_i\,d\vec{l}_i$$

(iii) Polarization:- The dielectric is polarized in the presence of electric field. The effect of field is to displace +ve & -ve charges and this displacement of charges causes/creates electric dipoles, and this effect is called Polarization of dielectric.

Polarization (P) is defined as the dipole moment per unit volume i.e

$$\vec{P} = p/V$$ It is a vector (C/m^2)

(iv) Polarizability :- When a dielectric material is placed in an electric field, the displacement of electric charges gives rise to the creation of dipole in the material. $P \propto E$ or $P = \alpha E$, where α is called Polarizability (Fm^2) or farad-m^2.

If solid material contains N no. of particles per unit volume, then $P = N\alpha E$

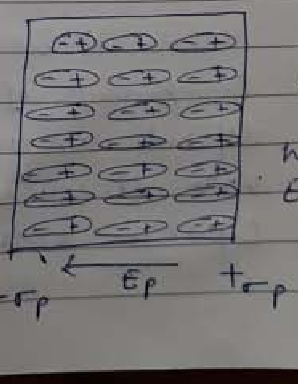
where $\alpha = \alpha_e + \alpha_i + \alpha_d$

Types of dielectrics -

(i) Non-Polar dielectrics :- A ~~ny~~ dielectric in which molecule ~~of the~~ a the centres of positive (distribution of proton) and centre of negative charges (distribution of electrons) coincide is called non-polar ~~ato~~ molecule and do not possess any electric dipole moment. e.g CO_2, CCl_4, H_2, N_2 & O_2.

(ii) Polar molecule (Dielectric) :- A Molecule of a dielectric in which centre's of positive and negative charges do not coincide but separated by a small distance is called Polar molecule. They work as electric dipole and have dipole moment. Eg are HCl, H_2O, $CHCl_3$

Polarization in Dielectrics :-



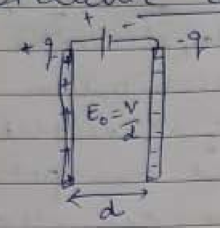
$E = E_0 - E_p$

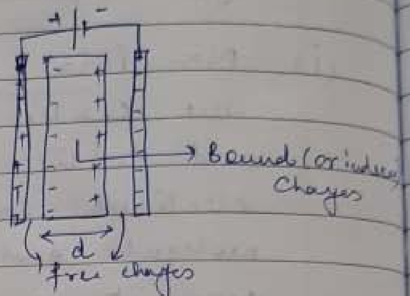
hence $E < E_0$.

The Phenomenon of orientation of the induced dipoles or the permanent dipoles in an external electric field to set the axis of the dipoles along the field is called electric polarization.

Due to polarization, molecules are so oriented that the negative charges are on the left and +ve charges are on the right. The medium as a whole remains electrically neutral as the +ve charge on the right is equal to the -ve charge on the left. Since the charges are not free they bound, they are called bound or fictitious charge, and the charges so obtained on the surface are called Polarization charge.

Dielectric Constant:-





$$C_0 = \frac{\epsilon_0 A}{d} = \frac{q}{V_0} \quad -(1)$$

$$C_d = \frac{\epsilon A}{d} = \frac{q}{V_d} \quad -(2)$$

Where ϵ is permittivity of this dielectric medium and $\epsilon > \epsilon_0$. V_d and C_d are the Potential difference between the plates and capacitance resp. with dielectric.

From eq. (1) and (2) we get

$$\frac{C_d}{C_0} = \frac{V_0}{V_d} = K = \frac{\epsilon}{\epsilon_0} = \epsilon_r \quad -(3)$$

Where K is called the dielectric constant or dielectric co-efficient of the medium, denoted by ϵ_r. It is defined as the ratio of a capacitance of a capacitor with dielectric to the capacitance of the same capacitor without dielectric.

It is greater than one and independent of shape or the dimensions of the capacitor but varies for different dielectric material (medium). The Permittivity of the medium (ϵ) is defined as

$$\epsilon = \epsilon_0 \epsilon_r = \epsilon_0 K$$

$$\epsilon_r = K = \epsilon / \epsilon_0 \quad -(4)$$

Thus the dielectric const (K) is also defined as the ratio of the permittivity of the medium to the permittivity of the vaccum, K for air or vaccum is equal to unity.

Three electric vectors: E, P and D

(i) Electric field Intensity E: The electric field Intensity at any point in the Electric field is defined as the force experienced by a unit +ve charge placed at that point.

$$\vec{E} = \lim_{q \to 0} \frac{\vec{F}}{q} \quad -(5) \quad \vec{E} \ \& \ \vec{F} \text{ are same direction}$$

$$E = \frac{q}{\epsilon_0 A} \quad (N/\text{Coulomb or } V/m) \quad -(6)$$

(ii) Polarization Vector $\vec{P}$:- In the Presence of an electric field, the molecules of a dielectric become polarized and gain electric dipole moment. The effect is called electric polarization. The Polarization Vector is defined as electric dipole moment induced per unit volume. It has the same direction as the electric field and denoted by $\vec{P}$ (C/m^2) (Coulomb/m^2).

If σ_p is the density of Polarization charge on the surfaces, P (Polarization Vector), A is the area of Crossection & l is the length of dielectric